SUPPLY CHAIN STRATEGY FOR TECHNOLOGY MANUFACTURING: A CASE STUDY

by

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Bachelor of Science in Electrical Engineering
University of Michigan (1995)

Submitted to the Sloan School of Management and the Department of Electrical Engineering and Computer Science in partial fulfillment of the requirements for the degrees of

Master of Science in Management and
Master of Science in Electrical Engineering and Computer Science

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ABSTRACT

This thesis explores a variety of logistics strategies for Qualcomm Wireless Business Solutions (QWBS), focusing on the OmniTRACS system and MVPc display. I develop and apply a model that considers the interactions of inventory processing and inventory movement in the context of total supply chain costs. My goal is to minimize purchased product inventory while reducing product lead-times. Without a formal model, supply chain organization decisions tend to replicate existing designs because it is difficult to find a better solution by trial and error due to the numerous alternatives and the number of variables involved.

To develop an understanding of the issues at QWBS, I began by researching technology manufacturing supply chains. I also developed a cost model for analyzing QWBS's supply chain. The final form of this model is a series of spreadsheets which accepts cost data, lead times, and variable demand as key inputs, and produces overall supply chain cost distributions. The supply chain is modeled as a series of processing nodes and transfer links. The model derives its results by simulating variable demand and summing the cost contributions of the nodes and links for each trial.

The supply chain research and the cost model provide Qualcomm with a realistic and usable tool to compare both intra- and inter-company supply chain designs in terms of overall channel costs. Furthermore, my results suggest that QWBS should focus its direct shipping supply chain efforts on customers whose demand variation is smaller than QWBS's overall customer average.

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SECTION 1: INTRODUCTION

1.1 PROJECT DESCRIPTION

Qualcomm Wireless Business Solutions (QWBS) plans to grow its sales without significantly increasing its manufacturing operations by introducing new products that depend more and more on purchased assemblies. For an older QWBS product variant, OmniTRACS with Display Unit, current purchased assemblies (or "ancillary products") comprise approximately 15% of the product's material cost. However, ancillary product material cost will increase to almost 50% for newer display products like the MVPc (in-cab display with personal computer processing functionality), and this trend is likely to continue. The two trends of increasing numbers of purchased assemblies and the increasing value of each assembly will combine to make managing ancillary product inventory levels a critical capability.

In addition to minimizing inventory levels, QWBS's inventory strategy has to facilitate short lead times for customer orders. The OmniTRACS product dominates the long-haul trucking communication market partly because of outstanding product reliability, but also because of QWBS's high levels of customer service. If it intends to push into new markets, it cannot let its order lead times begin to slip. QWBS's current supply chain strategy for ancillary items is to hold them at its San Diego manufacturing facility. When customer orders arrive, both ancillary and Qualcomm manufactured product is packed into a single box (masterpacked), for delivery to the customer.

To evaluate the relative efficiency of this strategy, in light of the changes in volume and value that are coming, supply chain alternatives need to be examined and a model needs to be developed that will facilitate comparisons. A viable alternative should reduce pipeline inventory and/or increase product velocity through that pipeline while reducing overall pipeline costs to improve upon the current system. A detailed cost model would help QWBS managers craft better supply chain strategies in a changing environment.

1.2 SCOPE & LIMITATIONS

This thesis evaluates the costs and benefits of a supply chain strategy in which QWBS suppliers deliver MVPc's directly to some of QWBS's customers (direct shipping). It weighs the direct shipping strategy's risks and rewards against those of the current system, and makes supply chain strategy recommendations for the QWBS manufacturing organization. In addition, this thesis develops a cost model to help formulate those supply chain strategy recommendations.

The cost model assumes that the different stages of the logistics systems take demand signals from their immediate downstream stage ("pull" system), which is not how QWBS currently operates. This assumption was made to both simplify the model and because QWBS is implementing Demand Flow Technology (TM) in its manufacturing facility and has plans to roll its pull methodology into the ancillary parts logistics system.

1.3 THESIS OVERVIEW

Chapter 2 provides background on QWBS and its market environment. It touches on the history of the business unit, the history of its core product OmniTRACS, and OmniTRACS's competitive landscape. It also outlines the current product flow for OmniTRACS ancillary products. Furthermore, Chapter 2 introduces the direct shipping supply chain alternative for MVPc's, discusses its strengths and weaknesses, and identifies alternatives.

Chapter 3 describes the cost model. First, this chapter describes the process by which research was conducted to gain an understanding of QWBS's supply chain. That process included interviews with external managers, with internal managers, and a review of academic literature. Chapter 3 continues by describing the design and the components of the model itself, along with the assumptions that went into its design. For detail on the individual inputs to the model, please refer to Appendix A.

Chapter 4 makes recommendations for QWBS's supply chain as indicated by the model's results. QWBS should target its Truck OEM customers for direct shipping for two reasons:

1. Truck OEM's already have some of the information technology infrastructure required for this kind of supply chain. Having some of the required infrastructure already installed reduces one of the major fixed costs associated with direct shipping.

2. The more stable demand from Truck OEM's lends itself to the cost structure of the direct ship strategy. The masterpack system enjoys economies of scale for displays shipped from the supplier to QWBS that the direct ship system does not. When low demand variation makes large daily shipments less probable, the direct ship system is consistently more cost effective.

For specific detail on the model's results, please refer to Appendix B.

2.1 COMPANY BACKGROUND

Qualcomm Wireless Business Solution's (QWBS's) main product is the OmniTRACS system. OmniTRACS is a satellite-based communication system designed primarily for long-haul trucking companies. OmniTRACS uses a proprietary communication technology that shares technical elements with the successful CDMA cell phone technology.

The OmniTRACS system provides individual freight haulers two-way wireless communication with their dispatcher, via the OmniTRACS network. Signals travel from the vehicle, up to orbiting satellites, back down to a Qualcomm-maintained signal-processing hub, and then via land-based telephone infrastructure to the dispatcher.

There are two main components to the OmniTRACS unit that reside on the freight vehicle. The first is a one-piece antenna / signal-processing unit (Integrated Mobile Communications Terminal, or "IMCT" for short), which is mounted on top of the vehicle and the second component is a display terminal mounted inside the vehicle, convenient to the operator.

The IMCT is manufactured by QWBS, but the displays are purchased from outside vendors. Recently, product improvements have included enhanced capabilities within the display terminal. These product advancements have taken display costs from about 10% of total product material cost for the venerable Display Unit (DU), to about 15% of total product material cost for the current Enhanced Display Unit (EDU), to about 40% of total product material cost for the upcoming MVPc.

This last display terminal, the MVPc, provides many capabilities of a personal computer like email, word processing and spreadsheets. QWBS marketing expects the MVPc terminal to be the most popular OmniTRACS variant going forward.

QWBS's market share in the long-haul freight transportation market is dominant. It has used intellectual property rights on its communication technology and high customer service levels to build a monopoly-like market share. The communication technology being highly cost-effective has allowed QWBS to charge an enviable margin on very competitive prices.

2.2 OMNITRACS' ANCILLARY PRODUCT FLOW

From an ancillary products point of view, the OmniTRACS system consists of the IMCT, the display unit, connecting cables, the display holster assembly, and other simple parts. The IMCT is manufactured and held in inventory at Qualcomm's San Diego facility. The displays, cables, and display holsters are all purchased from vendors with distribution centers in southwestern US states. These purchased parts are delivered to Qualcomm's San Diego facility and are held in inventory until they are needed for a customer order. When a customer order is received, order components are picked from inventory and re-packed such that a complete OmniTRACS system is contained within a single box or masterpack.

2.3 DIRECT SHIPPING

When analyzing changes to a supply chain, individual companies have to be aware of the impact that those changes will have on other the companies in the supply chain. Supply chain partner compensation, in the form of increased revenue and/or reduced costs, has to be commensurate with the work that is expected of them. Partners, who expend additional effort and expense to participate in supply chain improvement initiatives, but then do not receive a fair share of the fruits of those improvements, will be reluctant to contribute in the future.

As with every business venture, the goal of supply chain improvement is to improve profitability by reducing costs (less labor, equipment, transportation, etc.) and/or increasing revenue (more sales, markets, customers, etc). For supply chains, costs also include product depreciation and obsolescence, as well as customer ill will when customers can't get the product that they want or were promised. When intra-company inventory levels alone are used to buffer customer demand, these last two costs are inversely related. To reduce product depreciation and obsolescence one has to reduce inventory levels, risking stock-outs. To ensure product availability, one has to increase inventory levels risking stale inventory.

However, by taking an inter-company view of the supply chain, one can simultaneously reduce pipeline inventory while decreasing overall product lead-times. Decreasing product lead-times will make responding to customer demand easier and will reduce stock-outs. This paper examines a supply chain strategy where QWBS's suppliers ship MVPc's directly to QWBS's customers to achieve these two goals.

2.3.1. Direct Shipping Negatives

To analyze the impact that this change would have on the channel, first examine the negative consequences. By asking display suppliers to ship directly to customers, QWBS is increasing the amount of work that the suppliers' shipping organizations have to do. Instead of regular bulk orders shipped to Qualcomm's San Diego facility, the same average volume is comprised of orders that are now smaller and more frequent. In addition to more work for the supplier, there's more work for customers as well.

Customers will experience new product coordination costs. Instead of receiving a single box containing a complete system, they will receive the system in two parts and probably in two separate shipments. In addition, this direct ship method eliminates the possibility for complete system testing that QWBS can perform. This will result in additional cost to the customer if asked to perform it, or else to the supplier if asked to install quality control programs to obviate the need for a final system test.

2.3.2. Direct Shipping Positives

However, the positive aspects of a direct shipping change can outweigh the negatives, if the channel is appropriate, and with proper planning and execution. Additional costs to the customer and supplier can be addressed by reducing their costs elsewhere. The ultimate goal is to reduce the overall supply chain costs. If this is achieved, then savings can be distributed to reduce overall costs to each of the channel's participants. QWBS can pay suppliers more for supplying direct shipped products and can charge customers less for buying them when the overall channel cost reductions justify it.

Channel cost reductions in a direct shipping system include reduced delivery cycle time as inventory moves directly from suppliers to customers, as opposed to sitting in QWBS's inventory in between. This increased velocity reduces inventory costs and associated risks, it supports quality initiatives by making defects obvious and not hiding them in inventory, and it reduces cash-cash cycle time.

Furthermore, reduced inventory levels free QWBS warehouse space for more productive activities, and it makes QWBS warehouse personnel more productive by reducing the number of products that have to be picked and packed to complete an OmniTRACS order.

2.4 ALTERNATIVES

There are options other than direct shipping available to QWBS. For example, if QWBS determined that its process management costs for the direct ship system would be excessive, QWBS could consider outsourcing product delivery to a third-party logistics provider.

2.4.1. Third-party Logistics Alternative

In this situation, all ancillary product suppliers and Qualcomm would ship their products to the logistics provider, who would then bundle and deliver whole systems to the customer.

In addition to limiting process oversight costs on Qualcomm's part, outsourcing logistics could reduce overall channel costs by leveraging economies of scale and scope available to logistics providers. These logistics providers have the capability to spread communication infrastructure costs across a larger number of routes as their scale increases. They can also increase the utilization of their transportation resources through aggregation of independent, variable demand as their scope increases. And finally, QWBS's customers receive individually packaged systems from one source, supporting the customer service aspect of QWBS's brand.

One of the drawbacks associated with outsourcing to a third-party logistics provider would be the inevitable inflexibility. For example, while QWBS may want to expedite an order to please an important customer, the logistics provider may not, as it would decrease its route efficiency. If this scenario were considered before the initial agreement were finalized, the two parties could add whatever contractual language as necessary to please them both. However, not every potential conflict of interest can be imagined ahead of time and contractually resolved. When the inevitable conflicts do arise, both parties will refer to the contract, and rigidly pursue their individual best interest while remaining within the bounds of the contract.

Another drawback to outsourcing logistics is that it doesn't automatically reduce the amount of inventory in the supply chain. Unless the logistics provider initiates its own supply chain improvements, the ancillary inventory that is stored within QWBS's San Diego warehouse in the current system would simply by stored at the logistics provider's warehouse in the same amounts.

Channel complexity would also be increased if QWBS were to outsource logistics. One of the weakest links in communications along a supply chain is at corporate boundaries. By introducing another company, the communication system has to be that much more robust to accommodate it.

2.4.2. Status Quo Alternative

If QWBS management places sufficient value on consistent operation, continuing to deliver product using the current system may be preferable to both direct shipping and outsourcing to a third party logistics provider. By keeping the system as it is, QWBS need not worry about the inevitable mistakes and missteps associated with process change. Customers' receiving operations also needn't be disrupted, as they would receive the individually packaged systems as they have been receiving them.

QWBS also has the option to wait for new opportunities. The third party logistics industry is undergoing rapid growth in volume and capability. As the industry matures, and is able to gain more efficiencies of scale and scope, previously mentioned drawbacks such as a lack of inventory reduction and an increased need for communication capabilities could be economically addressed, making outsourcing the most economical alternative.

However, until logistics are outsourced, the current system would restrict plans for increased purchased products, as it would be difficult to scale. More warehouse space would be required in San Diego to accommodate the new purchased products. Operating the logistics system in its current state would also not achieve inventory reduction nor cycle time compression, both valuable cost reductions.

2.4.3. Vertical Integration Alternative

The final supply chain alternative that this paper will discuss is vertical integration. QWBS could itself begin manufacturing displays. Production schedules could be synchronized and the supplier's finished goods inventory could at best be eliminated, and at worst be replaced by work in progress (WIP). This option however should be one of last resort. Upstream vertical integration would require QWBS to develop new display manufacturing capabilities and would force it to interact with a whole new set of display component suppliers. QWBS would have to invest in new facilities and equipment at a time when its strategic vision is to decrease its emphasis on manufacturing.

3.1 BENCHMARKING

To develop a general understanding of the supply chain issues at QWBS, I began researching technology manufacturing supply chains through interviews and academic reading. I focused the interviews on technology companies that sold systems comprised of both manufactured and purchased products. Another criterion for the interviews was a company's use of technology in its supply chain. I targeted organizations that had embraced new communication systems like intranets and the Internet to help them manage inventory in their supply chains. The companies that were interviewed either in person or by survey were Cisco, Dell, and the contract manufacturer (CM) Flextronics.

The interview contact at Cisco was a supply chain manager who was responsible for supplier relationships. He was selected because of his role managing outsourced manufacturing organizations such as Flextronics. The contact at Dell was a supply chain manager who was responsible for managing third-party logistics providers. He was selected because of his role managing outsourced logistics. The contact at Flextronics was an account manager who was responsible for managing customer relationships, selected because of his role as a finished product supplier.

There were a few central themes that emerged from the interviews. The first was to use information technology (IT) infrastructure to quickly distribute information throughout the supply chain. Cisco routes Internet orders both to its internal information systems and to those of its suppliers immediately once a customer order is validated. Flextronics employs people who have access to Cisco's information systems to update order status data directly.

Another theme was experimentation with new systems to develop expertise and limit risk. Dell utilizes a merge-in-transit program for the continental Europe market where monitors move West from Asia while PC's move East from Ireland, but Dell has not expanded it to the US. Dell manages a separate Austin facility for "peripheral" items waiting to be joined with manufactured product, but it manages the merging process within Dell.

The last major theme that emerged from the interviews was that third-party logistics industry might be more viable in the near future. Cisco has made plans to partner with Federal Express to have it handle Cisco's logistics. Flextronics is planing to enter this product shipping market by increasing its logistics capabilities.

In addition to interviewing outside managers of technology manufacturing companies, I also interviewed internal managers at Qualcomm. I conducted numerous interviews of managers responsible for logistics, manufacturing, marketing and finance areas. These managers were selected because of their involvement with ancillary products and I focused the interviews in this area.

The central theme that emerged from the Qualcomm manager interviews was that while isolated supply chain improvement efforts were underway, there was no strategic effort to integrate these local optimizations to work toward a global optimum. For example, QWBS had set organizational goals like reducing Qualcomm-owned inventory stored in San Diego and reducing product lead times. Furthermore, QWBS had initiated programs for attaining those goals like Vendor Managed Inventory (VMI). However there was no one evaluation of the inter-company supply chain designed to reduce overall costs and / or improve performance.

I also reviewed academic work on supply chains. One theme deemed applicable to QWBS was that channel members should engage in mutually beneficial supply chain relationships. Where "mutually beneficial" would mean sharing in savings and profits (Corbett, 1999). Another theme was to shorten lead times and organize supply chains for flexibility in order to be able to react to changes (Fine, 1999). Finally, the theme emerged that one could replace certain inventory movement with customer and product information movement in the supply chain without disrupting lead-time performance (Tyndall et. al., 1998).

3.2 COST MODEL OVERVIEW

After conducting research into technology manufacturing supply chains, I built a spreadsheet-based model to help analyze MVPc supply chain costs for two configurations. The first configuration is the current state of the supply chain where displays move from supplier to QWBS and then on to the customer. In the second configuration, displays move directly from the suppler to the customer. The model takes detailed cost information for most aspects of the supply chain and returns the distribution of potential supply chain cost that results.

The model decomposes the QWBS supply chain into three processing nodes and three transfer links. The processing nodes represent locations where work is performed on a product or where inventory is held. There is one node each for the MVPc display supplier, the QWBS San Diego warehouse, and the customer. The transfer links represent the product being moved between processing nodes. There is one link each for the movement from supplier to QWBS, the movement from the supplier directly to the customer, and the movement from QWBS to the customer.

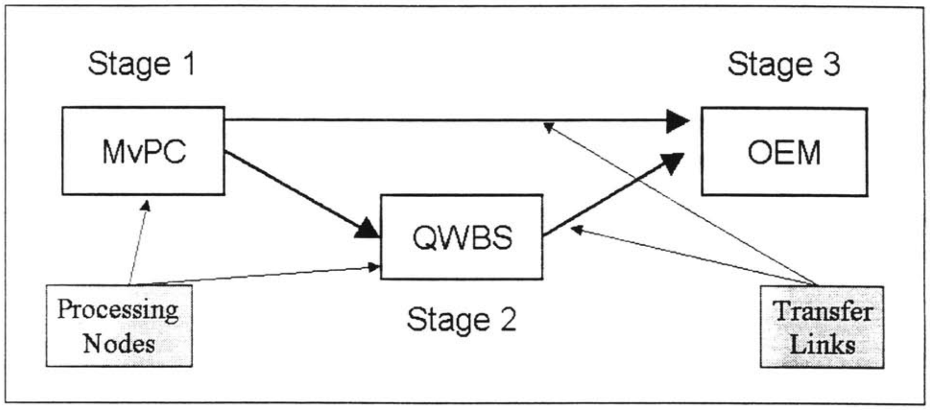

Figure 3.1 - Processing Nodes & Transfer Links

The direct ship supply chain is represented by the top path from the supplier directly to the customer. The masterpack supply chain is represented by the bottom path from the supplier, through QWBS, and on to the customer.

The purpose of this cost model is to simplify the complex task of evaluating the costs associated with an integrated, cross-company supply chain. The model is of specific value to QWBS because it is designed for the MVPc supply chain, but it is still general enough to be useful for other similar applications.

Costs for each processing node are separated into four categories. These four categories are then further subdivided into individual costs. Data are gathered and entered for each of these individual costs or category subdivisions. A description of the processing node categories and individual costs follows:

A) Direct Labor	Cost of direct labor required to handle / process product from receipt to shipment
1) Receiving	Labor associated with receiving
2) Conversion	Labor associated with converting raw materials to finished goods
3) Shipping	Labor associated with preparing for outbound shipping
B) Indirect Labor	Cost of labor attributed to product while not directly applied
1) Administrative	Indirect administrative labor associated with the product
2) Engineering	Indirect engineering labor associated with the product
3) Other	Other indirect labor associated with the product
C) Overhead	Other overhead costs attributable to this product
1) Facilities	Structures and machinery associated with the product
2) Utilities	Utilities consumed due to the product
3) Land	Real estate associated with the product
4) Other	Other overhead costs associated with the product
D) Process	Process control for quality
1) Process	Process control costs associated with the product

Costs for each transfer link are also separated into four categories. These four categories are then again further subdivided into individual costs. Data are gathered and entered for each of these individual costs or category subdivisions just as they were for the processing node individual costs. A description of the transfer link categories and individual costs follows:

A) Material	Cost of holding material in the supply chain
1) Material Cost	Amount paid for incoming product (used only to calculate opportunity cost)
2) Opportunity Cost	Represents Weighted Average Cost of Capital (WACC) and product lead time to account for opportunity cost of material
B) Inbound Transportation	Cost to ship product from previous node
1) Inbound Transportation	Shipping costs to bring product from previous node
C) Incoming Inspection	Cost of incoming product inspections
1) Equipment	Special equipment costs associated with incoming inspections
2) Labor	Labor costs associated with incoming inspections (where not included elsewhere)
3) Other	Other incoming inspection costs, like 3rd. party contracts, government regulations, etc. (where not included above)
D) Relationship Management	Infrastructure and communication costs
1) Extranet	Share of one-time costs of implementing an extranet or other intercompany communication systems (EDI, etc.)
2) Contract	Share of one-time costs associated with contracting for relationship norms and expectations
3) Other	Share of other one-time relationship management costs (where not included elsewhere)

The key inputs for the model are detailed cost data, lead times for moving product between processing nodes, and the product demand distribution. Detailed cost data such as labor, overhead, material, and relationship management form the basis of the model's analysis. Each of these cost components is either a one-time cost, a cost that is a function of time, or a cost that is a function of the volume of displays being moved through the supply chain. Product lead times, in conjunction with cost data like material cost and QWBS's weighted average cost of capital (WACC), produce inventory depreciation costs. The expected product demand variation, in conjunction with the simulation trials, attempts to model the demand uncertainty the supply chain will really encounter (for more detail on the cost model, see Appendix A).

The data used to populate the model were gathered predominately from interviews with internal managers. I used QWBS's cost and productivity data as a basis for estimating suppliers' and customers' costs for warehousing, information technology, and shipping. Where estimates were more difficult to make, such as for process control for quality and for relationship management, I focused on minimizing the difference in the errors introduced to both systems.

For example, I used $0 for the relationship / contract management cost for the masterpack system and $20,000 for that same cost for the direct ship system. While neither figure accurately represents that actual relationship / contract management cost for either system, their difference of $20,000 I believe is close to the increased burden that the direct shipping system puts on this corporate function. Where in this case the increased burden is approximated as 50 billable hours at $400 / hour. Using these relative cost measurements will reduce the accuracy of the absolute supply chain costs, but it should preserve the relative performance.

Beginning with the assumption that display demand followed a normal distribution, I reviewed historical shipment information over a three-month period in 1999 for the current OmniTRACS EDU product to estimate demand variance. I found that this product's mean daily demand was around 65 units, but with a standard deviation of over 100. Excluding one extraordinary day in which 586 units were shipped, the standard deviation is still over 75.

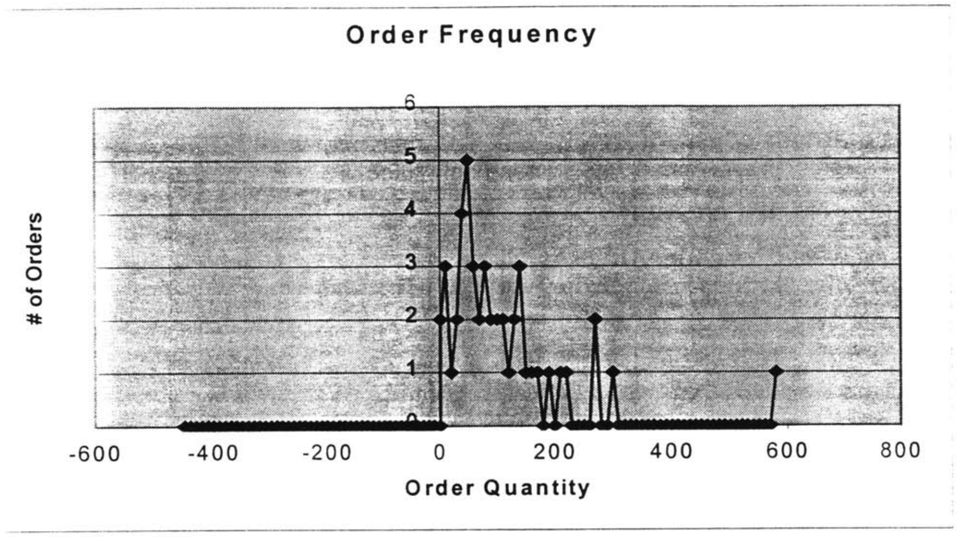

Figure 3.2 - EDU Order Quantity Frequency

This wide variance undermines the assumption that demand variance is normal because the normal distribution corresponding to this mean and variance indicates a high probability for negative order quantities.

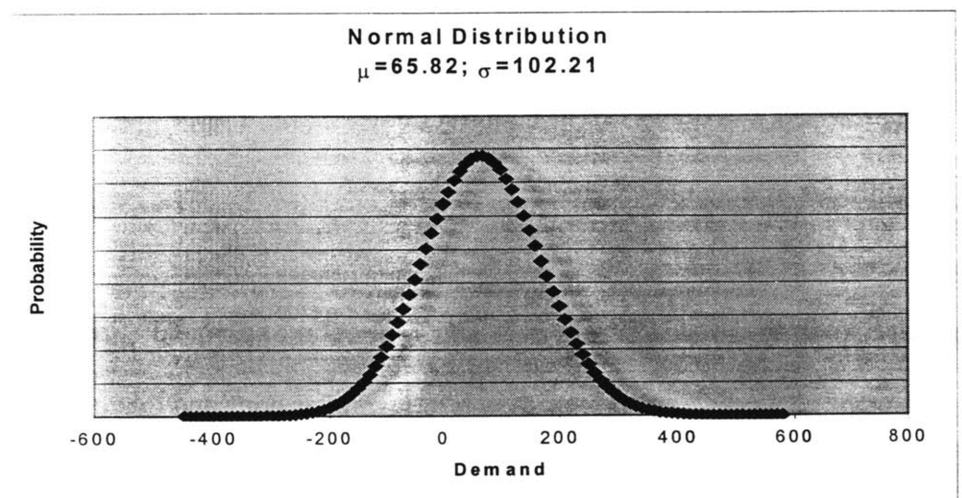

Figure 3.3 - Normal Dist. w/ Large Variation & Probable Negative Values

However, I think that the normal assumption is an appropriate approximation because the measured daily shipment variance does not exactly reflect the daily demand placed on the supply chain. These shipments could represent orders that had been built over a period of days or more. To account for orders that are built over a period of days, I measured demand variance on a weekly basis and the standard deviation dropped to around 30.

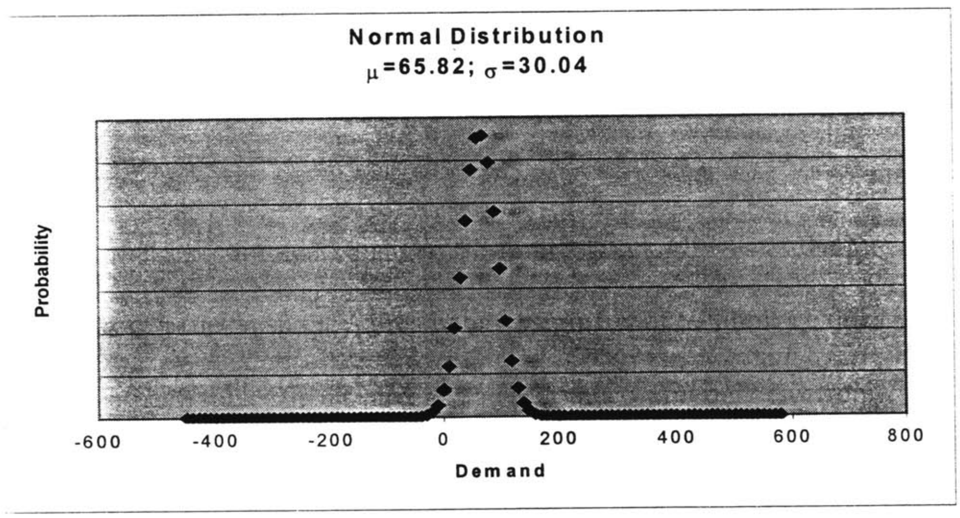

Figure 3.4 - Normal Dist. w/ Small Variation & Probable Negative Values

To explore the impact of demand variance on the supply chain, I ran simulations assuming different magnitudes of demand variance.

Where appropriate in the model, I made cost data a function of demand. For example the model assumes that labor costs are proportional to unit demand per hour and that overhead costs are proportional to unit demand per day.

Another important approximation is used in estimating depreciation costs. Unit depreciation costs are the product of QWBS's WACC, material cost and product lead-time between processing nodes.

$$UnitDepreciationCosts = (DailyWACC)*(MaterialCost)*(LeadTime)$$

Data for the WACC was obtained for Qualcomm as a whole from the 1999 annual report. This is not a precise measurement, but I believe that it is a fair approximation.

The last major approximation is related to the IT infrastructure that the direct shipping system would require. As the model reports supply chain costs on a "per unit" basis, the fixed cost for IT systems has to be divided by the total number of MVPc OmniTRACS systems that would be sold over the product lifecycle. This total lifecycle sales estimate was generated from initial marketing analysis reports predicting a 5-year lifecycle before planing to ramp production back down.

Some other assumptions that the model incorporates include the exclusion of supply chain participants upstream of QWBS's suppliers and downstream of QWBS's customers. I felt that including these extended channel members would make the model too complex to be useful. Another assumption in the model is that MVPc demand is determined by known customer orders. QWBS is already implementing this kind of "pull" demand system elsewhere in the manufacturing organization and plans to extend the project into other areas.

SECTION 4: CONCLUSIONS

4.1 RECOMMENDATIONS

This paper recommends that QWBS consider direct shipping of MVPc's from QWBS's suppliers to a subset of QWBS's customers. This change should be implemented first with QWBS's Truck Original Equipment Manufacturers (OEM's), and then evaluated for extension to the rest of the customer base. Truck OEM's comprise approximately 30% of QWBS's customer base by revenue. By targeting only this customer group initially, QWBS can demonstrate direct shipping's feasibility without the risk associated with a full-scale implementation. Furthermore, in light of the recent company divestitures of other manufacturing organizations, this evolutionary change may be easier to accomplish organizationally.

The main advantage of this proposal is a more efficient supply chain. Overall supply chain costs will be reduced by removing inventory from the supply chain and by reducing labor and transportation costs associated with handling that inventory. The model results suggest that for a high level of demand variation, mean supply chain costs for direct shipping would be over 3% less than the masterpack system. However, median supply chain costs for direct shipping would be almost 6% greater than the masterpack system.

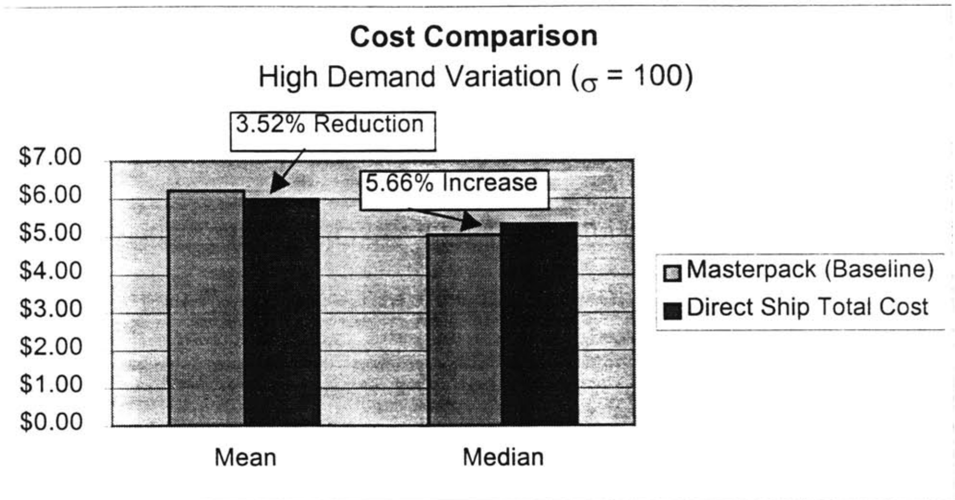

Figure 4.1 - High Demand Variation Cost Comparison

The standard deviation of supply chain costs for the masterpack system is $225.68 with a potential maximum cost of $13,877.75 / unit.

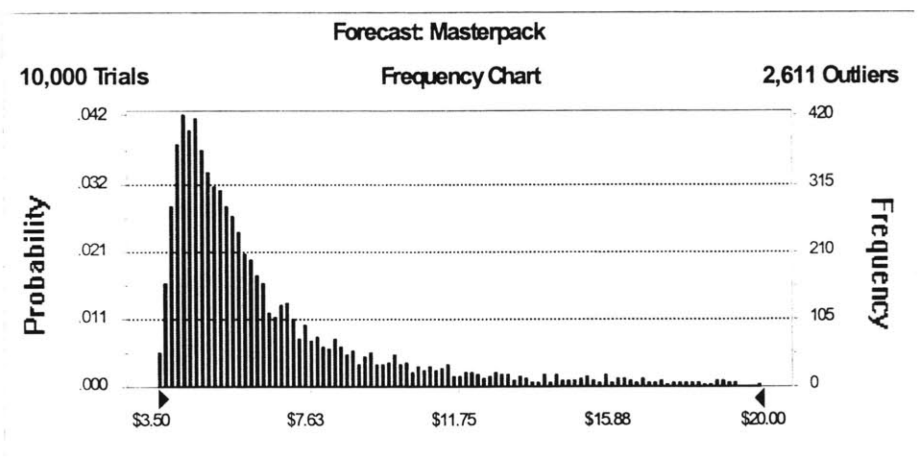

Figure 4.2 - Masterpack Supply Chain Costs for High Demand Variance

The standard deviation of supply chain costs for the direct ship system is almost half that of the masterpack system at $128.01 with a lower potential maximum cost of $7,874.23 / unit.

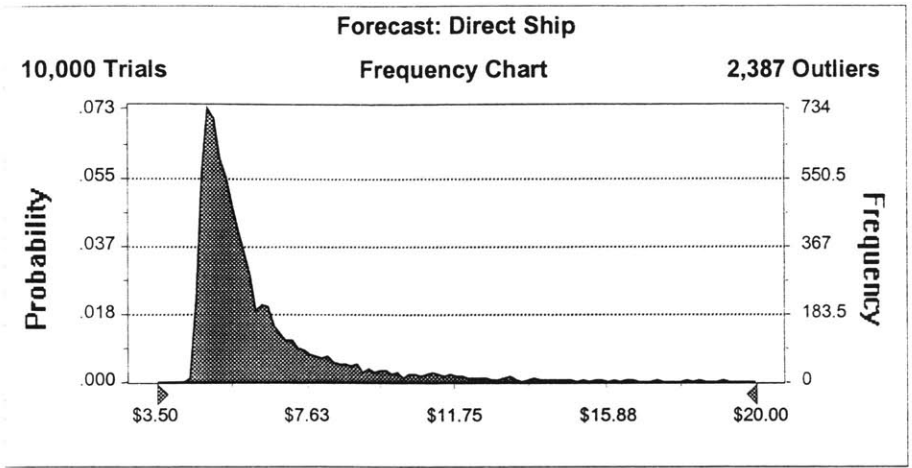

Figure 4.3 - Direct Ship Supply Chain Costs for High Demand Variance

One of the reasons that I recommend that QWBS target Truck OEM's as the initial customers for a direct shipping process because they already have significant technology infrastructure in place. The systems that Truck OEM's have installed to accommodate electronic data interchange (EDI) transactions with their suppliers will make tracking receipt of the MVPc separate from the OmniTRACS system easier. In addition, the orders that they place with QWBS are more predictable. The orders are more predictable because they depend on the OEM's planned production schedule. Using a more stable demand variance, similar to the calculated weekly demand standard deviation of 30, the direct shipping method resulted in an over 9% improvement over masterpacking measured by mean and an almost 6% improvement measured by median.

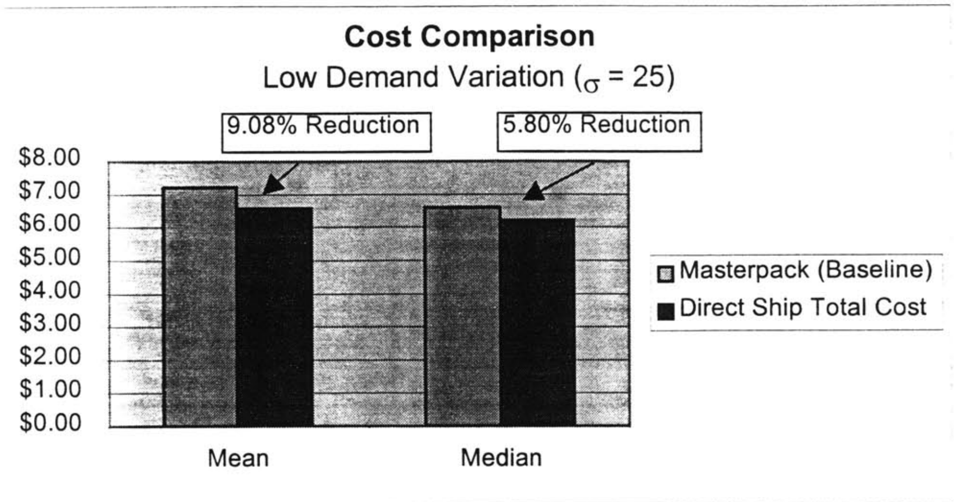

Figure 4.4 - Low Demand Variation Cost Comparison

The standard deviation of supply chain costs for the masterpack systems is $3.95 with a potential maximum cost of $257.09 / unit in this low demand variance scenario.

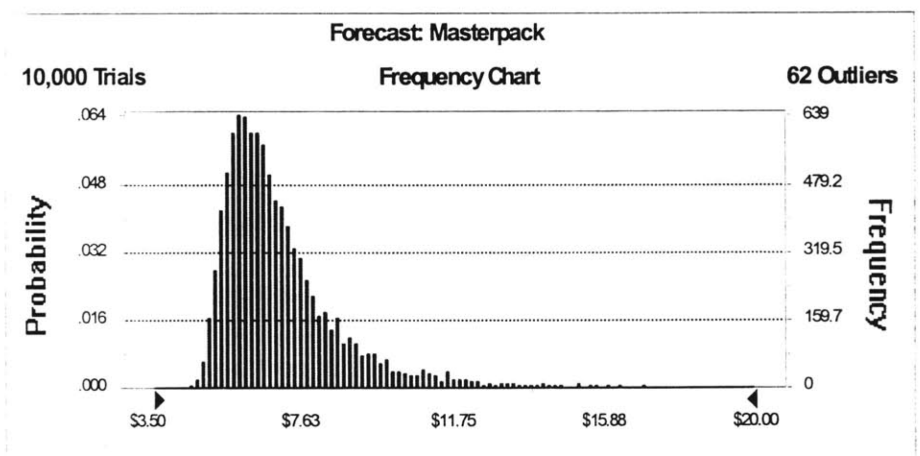

Figure 4.5 - Masterpack Supply Chain Costs for Low Demand Variance

The standard deviation of supply chain costs for the direct ship system is again lower then that of the masterpack system at $2.24 with a lower potential maximum cost of $148.23 / unit.

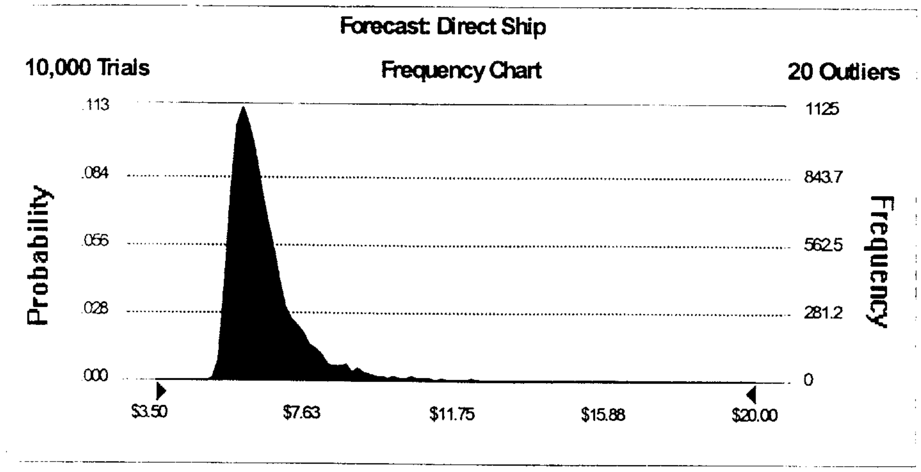

Figure 4.6 - Direct Ship Supply Chain Costs for Low Demand Variance

There are disadvantages associated with this proposal. For instance, direct shipping increases the complexity of the supply chain. Displays will move on two different paths, one direct and one through QWBS, until direct shipping is rolled-out to all customers. The return product flow is also more complex. Customers will expect one contact for service and warranty work so QWBS will have to manage the return of displays through its own facility.

There will also be significant up-front communication infrastructure costs. New systems and processes will be required to communicate order status and manage the convergence of the MVPc and the OmniTRACS system at the customer's location. QWBS will also lose the economies of scale it benefited from in bulk deliveries of MVPc's. As orders are distributed across both customer locations and QWBS's San Diego manufacturing facility, shipment sizes will shrink and per-unit-shipping costs will rise.

QWBS can take steps to mitigate these disadvantages. To reduce the impact of increased complexity, enhance supply chain communication and information systems to provide inventory and order status data. To avoid some of the costs associated with designing and implementing new systems, re-use Qualcomm's existing EDI processes and expertise. Admittedly, nothing can be done to retain the bulk order size for display deliveries. However, order quantities will fall and order frequency will increase regardless as ancillary products migrate to a "pull" system.

After successfully and more cost effectively direct shipping MVPc's to the Truck OEM's, QWBS should consider installation firm customers for direct shipping next. The cost model and experience from the MVPc implementation will help evaluate the feasibility of this customer group for direct shipping. More variable demand and higher requirements for on-time deliveries make this group more challenging, but this risk is offset by QWBS's typically bulk orders and the fact that they are already receiving mounting assemblies directly from suppliers.

4.2 POTENTIAL OBSTACLES

There are two other issues important to consider when QWBS makes plans for supply chain changes. One is to ensure that all channel members can profit from their participation. If a supply chain member is not profiting, but is participating only because QWBS was able to force it to, this company will not value the long-term relationship and it may cheat for short-term gains. The other issue is training. The inter-company processes and systems involved in the direct shipping recommendation are for the most part very different from the current QWBS processes and systems. Time and resources for user training should not be underestimated for any of the channel partners.

The model contains a spreadsheet for each of the three stages (processing node and inbound transfer link pairs) of each of the two supply chains. Note that not all costs are applicable for all stages. Applicable costs for a given stage are color-coded on the spreadsheet and a key indicates which colors are for Data Entry.

Stage 1 - Direct Ship

Cost	Description	Detail	$ / hr	$ / day	$ / ave. ship	$ / lifecycle	units / hr	units / day	units / ave. ship.	units / lifecycle	$ / unit	Total
Direct Labor	Cost of direct labor required to handle / process product from receipt to shipment.	Receiving	0				0				0	
		Conversion	0				0				0	
		Shipping	12				50				0.24	
		Total										0.24
Indirect Labor	Cost of labor attributed to product while not directly applied.	Administrative	0				0				0	
		Engineering	0				0				0	
		Other	0				0				0	
		Total										0
Overhead	Other overhead costs attributable to this product.	Facilities		0				0			0	
		Utilities		0				0			0	
		Land		0				0			0	
		Other		10				80			0.13	
		Total										0.125
Process	Process control for quality.	Total										0.5
Material	Price paid to previous stage for material.	Material Cost 0										
		Opportunity Cost		0				0			0	
		Total										0
Inbound Transportation	Cost to ship product from previous node.	Total			0				0			0
Incoming Inspection	Cost of incoming product inspections.	Equipment	0				0				0	
		Labor	0				0				0	
		Other	0				0				0	
		Total										0
Relationship Management	Infrastructure and communication costs.	Extranet				50000				78000	0.64	
		Contract				20000				78000	0.26	
		Other				0				78000	0	
		Total										0.897436

Key	
	Enter Data
	Not Applicable
	Calculated

Figure A.1 - Cost Data Input Spreadsheet for Direct Ship Stage 1

Each individual cost is entered in proportion to time (hours or days), product volume (average shipment), or is a one-time charge (lifecycle), and the cost per unit is calculated. The one exception is material cost, which is entered directly as cost per unit.

Where appropriate, costs are made a function of expected product demand. For example, the Overhead cost category for processing nodes requires units shipped per day as input. In general, this would be expected product demand.

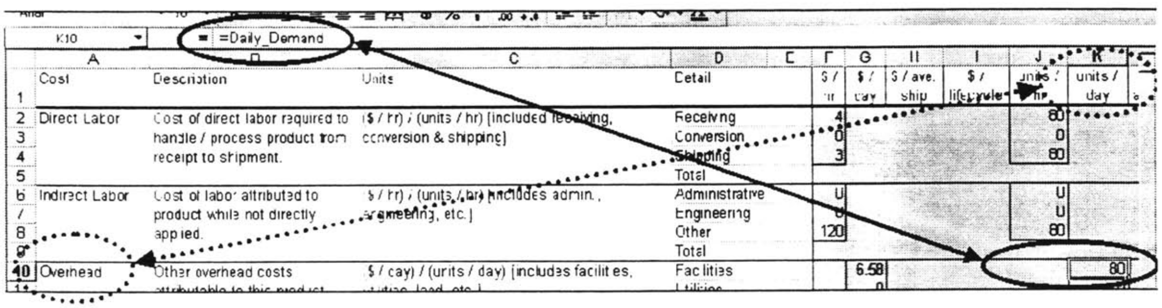

Figure A.2 - Cost as a Function of Expected Demand

Data for each cost category for each stage is summed, and those sums are represented on the Cost Overview spreadsheet. The Cost Overview spreadsheet provides a high-level view of supply chain costs. This view also presents total costs for each supply chain.

Costs Overview

Input Costs		Direct Shipping			Total	Masterpacking			Total
		Stage 1	Stage 2	Stage 3		Stage 1	Stage 2	Stage 3	
Conversion	Direct Labor	$ 0.24	$ -	$ 0.40	$ 0.64	$ 0.15	$ 0.09	$ 0.30	$ 0.54
	Indirect Labor	$ -	$ -	$ -	$ -	$ -	$ 1.50	$ -	$ 1.50
	Overhead	$ 0.13	$ -	$ 0.13	$ 0.25	$ -	$ 0.08	$ -	$ 0.08
	Process	$ 0.50	$ -	$ -	$ 0.50	$ -	$ 0.25	$ -	$ 0.25
Movement	Material	$ -	$ -	$ 0.82	$ 0.82	$ -	$ 1.64	$ 0.82	$ 2.47
	Inbound Transportation	$ -	$ -	$ 1.30	$ 1.30	$ -	$ 0.48	$ 1.30	$ 1.78
	Incoming Inspection	$ -	$ -	$ 0.03	$ 0.03	$ -	$ -	$ 0.03	$ 0.03
	Relationship Management	$ 0.90	$ 0.90	$ 0.90	$ 2.69	$ -	$ -	$ -	$ -
	Total	$ 1.76	$ 0.90	$ 3.58	**$ 6.24**	$ 0.15	$ 4.04	$ 2.45	**$ 6.64**

Variable	Value	Mean	St. Dev.
Daily Demand	80	80	100
WACC	0.15	N/A	N/A

Key		
	Enter Data	
	Not Applicable	
	Calculated	

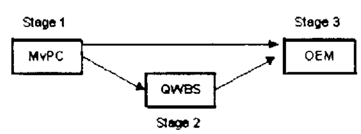

Figure A.3 - Cost Overview spreadsheet

To use this model, gather all of the cost data necessary to populate the detailed spreadsheets. In addition to cost data for the individual stages, the user has to determine the Weighted Average Cost of Capital (WACC) that the model will use, and information on the expected demand. Demand can be estimated by reviewing historical data for similar products, and it can be adjusted depending on the product's marketing staff's input. Assuming that demand follows a normal distribution pattern, the information that the model requires is mean and standard deviation of that demand.

Once all of the data is populated, the Cost Overview spreadsheet will present total cost supply chain costs, but it is representative of only the one demand value entered. To model the variation of demand, the Crystal Ball simulation software is used.

The Crystal Ball simulation software generates random numbers using the mean and standard deviation values entered. The software tracks the resulting values of the total supply chain cost cells for each trial, over a large number of trials, and reports statistics on total supply chain costs. To set-up the spreadsheet model for a Crystal Ball simulation, define the demand cell as the "Assumption", and the two total supply chain cost cells as "Forecasts", and then run the simulation for a large number of trials.

The output of the cost model is in the form of Crystal Ball reports. Complete results for the Direct ship system, assuming low demand variation (Standard Deviation of 25) follow:

Summary:
Display Range is from $3.50 to $20.00
Entire Range is from ($13.21) to $148.30
After 10,000 Trials, the Std. Error of the Mean is $0.02

Statistics:	Value
Trials	10000
Mean	$6.58
Median	$6.22
Mode	---
Standard Deviation	$2.24
Variance	$5.02
Skewness	31.23
Kurtosis	1,709.54
Coeff. of Variability	0.34
Range Minimum	($13.21)
Range Maximum	$148.30
Range Width	$161.51
Mean Std. Error	$0.02

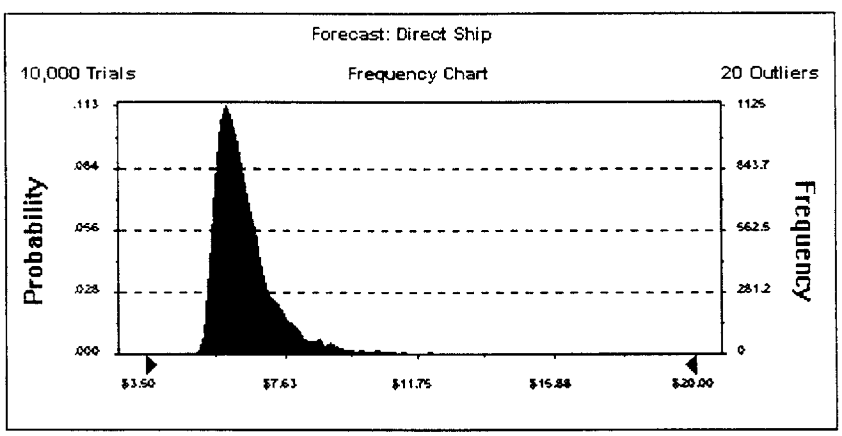

Figure B.1 - Low Variation, Direct Ship Summary Statistics

Complete results for the Masterpack system, assuming low demand variation (Standard Deviation of 25) follow:

Summary:

Display Range is from $3.50 to $20.00
Entire Range is from ($27.64) to $257.09
After 10,000 Trials, the Std. Error of the Mean is $0.04

Statistics:	Value
Trials	10000
Mean	$7.23
Median	$6.60
Mode	---
Standard Deviation	$3.95
Variance	$15.59
Skewness	31.23
Kurtosis	1,709.54
Coeff. of Variability	0.55
Range Minimum	($27.64)
Range Maximum	$257.09
Range Width	$284.73
Mean Std. Error	$0.04

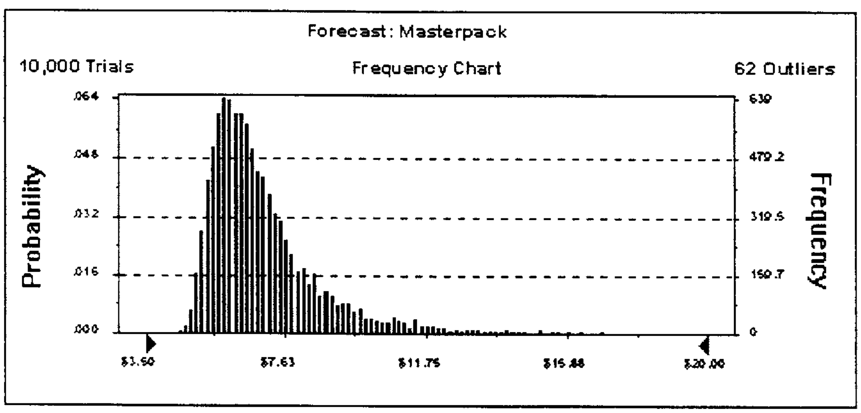

Figure B.2 - Low Variation, Masterpack Summary Statistics

Complete results for the Direct ship system, assuming high demand variation (Standard Deviation of 100) follow:

Summary:
Display Range is from \$3.50 to \$20.00
Entire Range is from (\$7,948.21) to \$7,874.23
After 10,000 Trials, the Std. Error of the Mean is \$1.28

Statistics:	Value
Trials	10000
Mean	\$6.00
Median	\$5.34
Mode	---
Standard Deviation	\$128.01
Variance	\$16,386.58
Skewness	2.74
Kurtosis	3,006.04
Coeff. of Variability	21.32
Range Minimum	(\$7,948.21)
Range Maximum	\$7,874.23
Range Width	\$15,822.45
Mean Std. Error	\$1.28

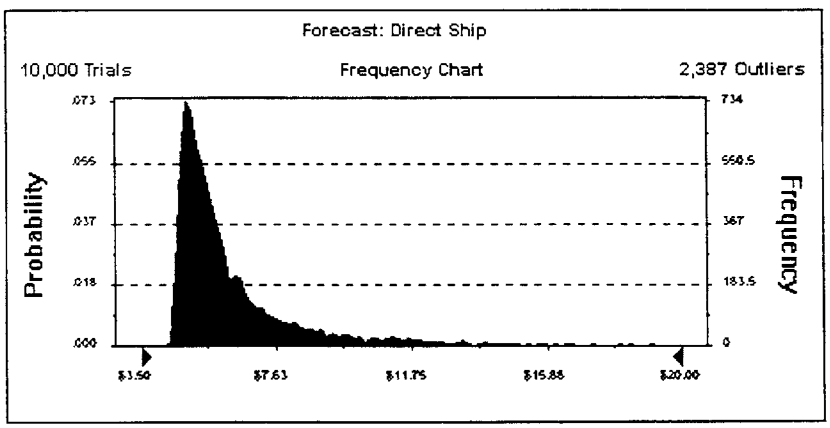

Figure B.3 - High Variation, Direct Ship Summary Statistics

Complete results for the Masterpack system, assuming high demand variation (Standard Deviation of 100) follow:

Summary:

Display Range is from $3.50 to $20.00
Entire Range is from ($14,016.90) to $13,877.75
After 10,000 Trials, the Std. Error of the Mean is $2.26

Statistics:	Value
Trials	10000
Mean	$6.22
Median	$5.05
Mode	---
Standard Deviation	$225.68
Variance	$50,931.09
Skewness	2.74
Kurtosis	3,006.04
Coeff. of Variability	36.27
Range Minimum	($14,016.90)
Range Maximum	$13,877.75
Range Width	$27,894.65
Mean Std. Error	$2.26

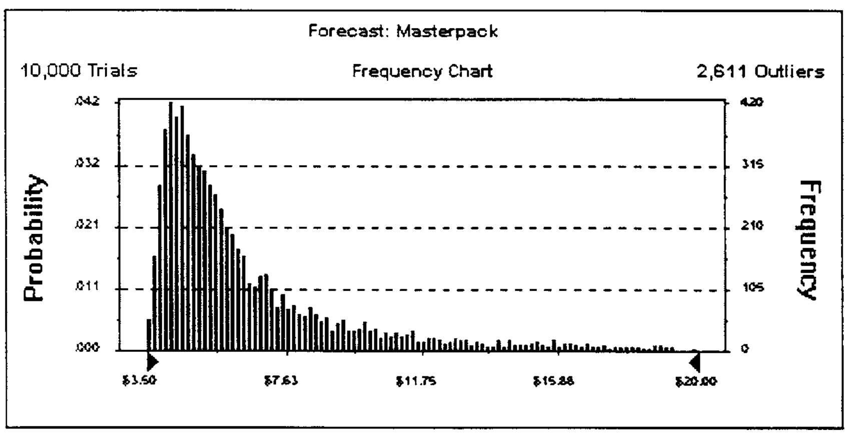

Figure B.4 - High Variation, Masterpack Summary Statistics

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